UCRL-JC-123609 Abs

Impact of Anthropogenic Sulfur Emissions on Cloud-Climate Interactions

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Preference of paper presentation: oral Session: S3, S5

The potential effects of atmospheric aerosols from anthropogenic sulfur emissions on global climate changes have received a considerable amount of attention recently. Concerns are expressed regarding a possible change in the global energy budget as a result of variations in the clear sky albedo (direct effect) as well as variations in the cloud optical properties (indirect effect). In this paper, we use a coupled climate/chemistry model with cloud nucleation processes parameterized in terms of local aerosol number, sulfate mass concentration, and updraft velocity, to investigate indirect radiative forcings by anthropogenic sulfate-containing aerosols. With different approaches for the formation of anthropogenic sulfate and its relation to aerosol size distribution, we estimate that the indirect forcing may range from -0.6 to -1.6 Wm^{-2} and reduces to -0.4 to -1.1 Wm^{-2} if a prescribed marine background particle number concentration is universally applied over the ocean. Contrary to the direct effect which is more significant over land, the indirect effect is much more pronounced over the ocean where the clouds are relatively optically thin. The maximum of indirect forcing is located over the Atlantic ocean near the coastline of North America. Our simulations indicate that anthropogenic sulfate-containing aerosols may result in important increases in reflected solar radiation, which would mask locally the warming from increased greenhouse gases. We also compare the simulated cloud drop effective radii with those retrieved from satellite data to validate the accuracy of our cloud drop parameterizations.

* Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.